Sinnissippi Alliance for the Environment
326 North Avon Street
Rockford, Illinois 61103

OPINION

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I. CONTENTIONS

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DAARE/SAFE Contention 9(a) -Waterhammer

DAARE/SAFE Contention 9(a) raises a concern over the possibility of a waterhammer event occurring in the feedwater bypass line at the Byron Station. Specifically, the contention addresses solely the question of whether or not the steam generator feedwater bypass line installed in Byron will be susceptible to bubble collapse waterhammer such as the one that occurred in the feedwater bypass line at the KRSKO plant in Yugoslavia in mid-1981. Bubble collapse waterhammer is a phenomenon that can occur when a volume of steam is trapped in an enclosed area, such as a pipe, by slugs of water. Cold water in the slugs would cause the steam to condense rapidly, thereby triggering a sequence of events that could cause a waterhammer event resulting in damage to the pipe and/or its supports.

Applicable Law

Before an operating license may issue, NRC must find that reasonable assurance exists such that the activities authorized by the operating license can be conducted without endangering the health and safety of the public and that such activities will be conducted in compliance with the Commission's regulations. 10 C.F.R. 50.57 (a) (3). One of the means for statisfying the requirements imposed by this regulation is to comply with the General Design Criteria for light water nuclear power reactors set forth in Appendix A to 10 C.F.R. Part 50.

These criteria establish principal design requirements for determining reactor safety. With regard to the potential for the occurrence of waterhammer in the feedwater bypass line, General Design Criterion 4 "Environmental and missle design bases" states in pertinent part:

> Structures, systems, and components important to safety shall be . . .appropriately protected against dynamic effects . . .that may result from equipment failures and from events and conditions outside the nuclear power unit.
>
> The actual review and/or evaluation for the design for or avoidance of water hammer is normally reviewed through different portions of the safety review plan. (Finding 1)

Section 15.2.8 of the Standard Review Plan, NUREG-75/087, describes the review pertinent to the evaluation of potential water hammer effects, as:

> APCSB reviews the auxiliary feedwater system to verify that it can function following a feedwater line break, given a single active component failure and with either onsite or offsite power. This review is performed as described in Standard Review Plan (SRP) 10.4.9.
>
> RSB reviews the auxiliary feedwater system to confirm that the flow provided is acceptable for controlling the transiant following a feedwater line break.
>
> MEB evaluates potential water-hammer effects on safety valve integrity.
>
> The ability of the auxiliary feedwater system to supply adequate feedwater flow to the unaffected steam generators during the accident and subsequent shutdown is evaluated by APCSB as to availability and by RSB as to capability to effect an orderly shutdown. Since auxiliary feedwater system designs are diverse and may require both automatic and manual actuation, preoperational tests should be specified to identify any necessary operator actions and to determine the maximum times permitted for their completion.

Waterhammer events such as occurred at KRSKO, create a "dynamic effect" against which systems important to safety are to be "appropriately protected." The feedwater bypass line is "important to safety" because this line serves as part of the Auxiliary Feedwater System which is designed to facilitate safe plant shutdown in the event of a loss of heat sink accident. (Finding 5) Preoperat-

ional testing is specified as a means to determine whether the function of the auxiliary feedwater system has been appropriately protected against the dynamic effect. The issue before us then is whether the auxiliary feedwater system at the Byron plant is appropriately protected against the dynamic effects of a KRSKO-type waterhammer event so as to meet Standard Review Plan criteria.

DA[illegible]/SAFE stipulated Contention 9(a) suggests that there should be a demonstration that a KRSKO-type waterhammer event will never occur at Byron. (Finding 3) In view of the standard set forth in General Deisgn Criterion 4, and applicant and staff witness testimony, the Contention may set forth an overly strict acceptance criterion. (Finding 47) However, although General Design Criterion 4 does not require a guarantee that a KRSKO-type waterhammer event will not occur at Byron, operation of the Byron plant with the proposed implementation of Westinghouse recommendations to mitigate waterhammer should be required to meet the "appropriate protection" standard.

Byron and KRSKO Steam Generator Design

Byron and KRSKO share the same model of steam generators, the Westinghouse Model D preheater counterflow type steam generator. They also have a common design of feedwater systems which serve these steam generators. There are basically three feedwater systems: the Main Feedwater System, the Feedwater Bypass System, and the Auxiliary Feedwater System. The last two systems introduce feedwater into the steam generator through an auxiliary nozzle located in the upper shell of the vessel. The Feedwater Bypass System was specifically designed to limit the possibility of occurrence of waterhammer events in the preheater section of the steam generator which is located inside the lower shell of the vessel adjacent to the main feedwater nozzle. The Feedwater Bypass System accomplishes this purpose by diverting cold feedwater to the auxiliary nozzle through the feedwater bypass line. (Finding 5) The waterhammer event considered here, however, did not occur in the preheater section, but in the

Feedwater Bypass System; specifically, the feedwater bypass line.

The KRSKO Waterhammer Event

The Applicant's expert witness on the waterhammer phenomenon reconstructed The KRSKO waterhammer event based on the available data. The event was a "bubble collapse" type waterhammer. The waterhammer apparently occurred during Hot Functional Testing of the Auxiliary Feedwater System pumps in July, 1981, but damage was not discovered till early August, 1981. The first indications of the waterhammer event were the discoveries of blistered paint on the pipes of the Auxiliary Feedwater Svstem as far back as the motor driven pumps, movement of several pipe hangers, and piping, and a quarter-inch bulge on a six to eight inch section of the bypass piping within containment near the secondary shield wall. (Findings 2, 4)

As a result of the event, the section of bypass piping containing the bulge was replaced. (Finding 6)

The evidence gathered during the assessment of the damage at KRSKO provided a basis for a reconstruction of the event as related by Applicant's expert witness, although he stated the exact time and sequence of events is not known. (Finding 7) Apparently, auxiliary feedwater check valves "which were known to leak" permitted backleakage through that system. Secondly, the water level in the steam generator fell below the discharge end of the internal extension of the auxiliary nozzle, thus allowing steam to flow out through the auxiliary nozzle and into the Feedwater Bypass System piping. With steam present in the bypass piping, the Auxiliary Feedwater System motor driven pumps were started as part of Hot Functional Testing, thereby introducing cold water into the bypass piping. The cold water rapidly condensed the steam and thus caused the waterhammer. (Findings 8, 9)

The Westinghouse Recommendations

Westinghouse has made four recommendations to Applicant to avoid a KRSKO-

type waterhammer event in the Feedwater Bypass System at the Byron Station. First, temperature sensors should be installed on the bypass piping close to the auxiliary nozzle to detect backleakage of hot water or steam. Applicant's Assist-Superintendent of Operations at Byron, witness Pleniewicz, testified that the temperature monitoring system will consist of temperature sensors on the feedwater piping adjacent to the auxiliary feedwater nozzle on each of the steam generators at Byron, which will feed information to the plant process computer, programmed to alarm when an abnormally high temperature is detected in the bypass piping. Temperature sensors will provide continous checking on check valve leakage, however as only one of the 6-inch valves and two of the 8 four-inch valves will be routinely inspected during refueling and maintance outages, these temperature sensors will be the relied upon indication of check valve condition. The temperature sensors used will be RTD's, which Pleniewicz admitted have been known to fail. (Findings 10, 11, 12, 13, 14)

NRC Staff witness, Serkiz, conceeded the possibility that a schedule of check valve or sensor maintance might help reduce the possibility of water hammer bubble collapse at a facility, but neither he nor Applicant witness, Carlson, were familiar with check valve or temperature sensor maintance or inspection proceedures. (Findings 15, 16, 17)

Second, in the event backleakage in the system is detected, Westinghouse has recommended that the bypass piping should be slowly refilled or the plant brought to a cold shutdown condition. The recommended refill rate was one w which was derived from an analytical study done by the Westinghouse R & D Center, but applicant is still in the process of developing procedures to enable the reactor operator to perform the task, and the hot functional testing itself will determine whether or not the tempering flow system at Byron can achieve the low flow rate as recommended. (Findings 18, 19, 20, 21)

Third, Westinghouse recommended that the water level in the steam gener-

ator be maintained above the auxiliary nozzle discharge pipe as much as possible. In general, the water level in the steam generators would not fall below the auxiliary nozzle discharge pipe, unless under an accident situation such as a feed line break. (Finding 22)

Fourth, the check valves of the Auxiliary Feedwater System should be maintained to minimize backleakage. As indicated earlier, although applicant witnesses stated stated that some of the valves at Byron will be routinely inspected during outages, temperature sensors with some unreliability will be the sole continous monitor of check valve condition. (Findings 12, 13, 14)

The Staff Review

The KRSKO water hammer event is within the purview of NRC Unresolved Safety Issue A-1, Waterhammer. Waterhammer is treated as a generic issue by the NRC yet, every instance of waterhammer, including bubble collapse waterhammer is considered to be plant specific. (Findings 23, 24)

The NRC does not have a task force studying water hammer. The Auxiliary Systems Branch and the Reactor Systems Branch are the primary branches involved in reviewing waterhammer. With the exception of the International Atomic Energy Agency visit to KRSKO, which concerned examination of the Flow-induced Vibration phenomena at that plant, neither of these two branches have directly investigated the KRSKO waterhammer event. (Findings 25, 26, 27)

The Staff witness, Serkiz, the task manager for Unresolved Safety Issue A-1, Waterhammer, was responsible for conducting the NRC evaluation of the KRSKO event, the KRSKO and Byron plant designs, and the Westinghouse recommendations. As Serkiz stated, Staff's evaluation of the KRSKO waterhammer event has been limited to review of information it recieved from Westinghouse and applicant at a meeting and through several items of correspondence. (Findings 28, 29, 30)

Staff's evaluation also relied in part on NUREG/CR-3090 "Evaluation of Waterhammer Potential in Preheat Steam Generators", which was introduced into evidence as Board Exhibit 2, in reaching their conclusions about the generic

implication of bubble collapse waterhammer events to preheat steam generators, and in this case, to Byron. (Findings 31, 32)

NRC Staff did not participate directly in drawing up NUREG-3090, but Serkiz provided the contractor with the details concerning the KRSKO event and design specifics for the McGuire, Summer, and Byron plants. (Finding 33)

Other than information related to backleakage, NRC Staff was not able to obtain explicit details of the type of preoperational tests being run at the moment of the DRSKO event, including as to whether proceedures were being followed or specialty tests being performed. Lacking the specifics on what occurred, Staff categorized the KRSKO event as a plant specific event, not generic in nature. Staff's conclusion that the event was plant specific and not generic was not intended to imply it could not occur in U.S. domestic steam generators. Rather, the KRSKO event reveals that a waterhammer due to bubble collapse can occur in the Auxiliary System of preheat steam generators. (Findings 34, 35, 36) Staff review of the KRSKO event was neither thorough or independent from that of Westinghouse or Edison.

Serkiz stated that the Westinghouse recommendations constitute good engineering design practices and prudent operating procedures. He clarified it by saying it was based upon the assumption that good engineering design practices and prudent operating procedures would be followed in implementing those recommendations. Upon that basis he was able to reach the conclusion that had those corrective measures been in place at the time of the KRSKO event, it likely would not have occurred. By that, he does not mean to imply that instances of faulty design or operation do not occur, as of course KRSKO demonstrated, it's cause attributed to backleakage through auxiliary feedwater check valves "which were known to leak". (Findings 37, 38, 39, 40, 41)

With respect to the Westinghouse recommendations, witnesses stressed the contributing effectiveness of the continous tempering flow to be provided to the steam generator auxiliary nozzle to minimize backleakage of steam from the

steam generator during power operation. Applicant has indicated though that this flow will not be present during the heat-up phase; and, during cooldown and hot standby, the feedwater supplied through the auxiliary nozzle is relatively small, not always enough to permit a continous flow so that the opportunity for steam backleakage does exist if valve failure and low water level occurs. (Findings 41, 42)

According to the testimony of Applicant and Staff witnesses, the KRSKO waterhammer event did not compromise the ability of the affected systems to function. The Staff witness testified that similarly, there would be no consequences if a KRSKO-type waterhammer event of the same magnitude occurred at Byron, i. e. if there was a pipe rupture, there would be no breach of the primary coolant system and thus no release of radiation. The facts remain however that the KRSKO event did result in damage; was at the upper end in magnitude of such possible events involving that plant system, and that the pipe could have ruptured had it been larger. (Findings 4, 43, 44, 45, 46)

Furthermore, as Applicant's witness said, "It should be clearly stated that waterhammer will continue to occur", and the number of instances that it may occur over the lifetime of a steam generator cannot be predicted. As noted earlier, the Feedwater Bypass System was developed and implemnted to reduce the possibility of bubble collapse water hammer occuring in the preheater of preheat steam generators. In it's development there was no testing conducted by Westinghouse prior to the KRSKO event which could have led it to conclude that the bypass system would be successful without, in turn, inducing waterhammer in the bypass line itself. The removal of a fast-acting type check valve from the Byron Auxiliary Feedwater System at Byron from it's position by the auxiliary feedwater nozzle, due to concern over possible "acoustical" waterhammer occurance under at least one accident sequence indicates the Auxiliary System may be susceptible to more than one type of waterhammer. (Findings 47, 48, 49)

50, 51)

It is conveivable that the results of a bubble-collapse waterhammer and classical waterhammer events could be the same in their effects on piping systems. Both result in a change in water pressure which has the potential for damaging piping components, and possible piping rupture. There are metal fatigue factors associated with bubble collapse waterhammer occurring in the preheater section of a steam generator, and as Carlson admitted, all bubble collapse waterhammer events have common elements regardless of where they occur. Their effect differs only according to the geometry of their location, whether they occur in piping, preheater passes, etc. (Findings 53, 54, 55, 56)

Westinghouse anticipates Bypass System failure to occur on four occasions within the 40-year lifespan of a steam generator. The initial susceptibility of the Byron steam generators or feedwater system to bubble-collapse waterhammer has yet to be determined in preoperational testing. The Byron plant will essentially be the first operational plant to implement the Westinghouse recommendations with a feedwater system representative of the type of system at the KRSKO plant prior to the event. NRC Staff is comtemplating changes to the Standard Review Plan as part of the resolution of the Waterhammer issue, but it has not been shown what these changes will be or that preoperational testing will encompass them. Applicant has not demonstrated that the preoperational procedures or operation plans being developed can specifically address feed line breaks or accident sequences so as to maintain Auxiliary Feedwater System integrity to meet Standard Review Plan criteria. (Findings 57, 58, 59, 60)

Conclusion

Based upon the uncontroverted evidence in the record, the Board finds that Applicant's stated intention to implement the Westinghouse recommendations; without demonstration that preoperational procedures or operation plans being developed will specifically address feed [redacted] line breaks or accident sequences

and changes currently comtemplated by Staff, does not constitute "appropriate protection" for the steam generator Auxiliary Feedwater System against the dynamic effects of KRSKO-type waterhammer events occurring at Byron. Furthermore, the Board finds that there has been insufficient determination of the nature of the KRSKO event and it's generic implications to conclude to conclude that possible recurrences of it at Byron do not constitute a significant health and safety concern, particularly given the test nature of the plant with respect to the Westinghouse recommendations.

FINDINGS OF FACT

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DAARE/SAFE Contention 9(a) - Waterhammer

1. "The actual review and/or evaluation for the design for or avoidance of water hammer is normally reviewed through different portions of the safety review plan." (Serkiz, Tr. 1012)

2. The KRSKO waterhammer event was a "bubble collapse" type. (Carlson, Tr. 930)

3. Applicant, Staff, DAARE/SAFE, and the League stipulated by an agreement dated February 15, 1983, that, the final language of DAARE/SAFE Contention 9(a) shall read as follows for litigation:

> During recent start-up tests at the KRSKO plant in Yugoslavia, which has steam generators which are similar in design to those at Byron, the plant experienced a bubble collapse waterhammer event in the feedwater bypass line. Applicant should be required to demonstrate that a similar event will not occur at Byron.

4. The waterhammer apparently occurred during Hot Functional testing of th Auxiliary Feedwater System pumps in July, 1981, but damage was not discovered till early August, 1981. The first indications of the waterhammer event were the discoveries of blistered paint on the pipes of the Auxiliary Feedwater System as far back as the motor driven pumps, movement of several pipe hangers, and piping, and a quarter-inch bulge on a six to eight inch section of the bypass piping within containment near the secondary shield wall. (Carlson, Test. 8, 11-12)

5. Byron ard KRSKO share the same model of steam generators, the Westinghouse Model D preheater counterflow type steam generator. They have a common design of feedwater systems which serve those steam generators. The Feedwater Bypass System was specif-

ically designed to limit the possibility of waterhammer events in the preheater section of the steam generator which is located inside the lower shell of the vessel adjacent to the main feedwater nozzle. The Feedwater Bypass System accomplishes this purpose by diverting cold feedwater to the auxiliary nozzle through the feedwater bypass line. (Carlson, Test., pgs. 5-8)

6. As a result of the event, the section of bypass piping containing the bulge was replaced. Also the hanger damage was repaired, and the check valves were refurbished. (Carlson, Test., 13)

7. The KRSKO event is believed to have occurred during hot functional testing in July of 1981. Because of the nature of the testing and the damage observed Westinghouse came to the conclusion that a bubble collapse water event had occurred, although its not possible to specify exactly what the conditions were when it happened. (Carlson, Tr., 1086-1088)

8. The cause was attributed to backleakage through auxiliary feedwater check valves "which were known to leak" and were later refurbished. (Serkiz, Test., 2; Tr., 951)

9. The waterlevel in the steam generator fell below the discharge end of the internal extension of the auxiliary nozzle, thus allowing steam to flow out through the auxiliary nozzle and into the Feedwater Bypass System piping. With steam present in the bypass piping, the Auxiliary Feedwater System motor driven pumps were started as part of Hot Functional Testing, thereby introducing cold water into the bypass piping. The cold water rapidly condensed the steam and thus caused the waterhammer. (Carl-

son, Test., 9-10; Tr., 1086-90)

10. The corrective measures Westinghouse has recommended are: (a) maintain steam generator water level above the auxiliary feedwater discharge pipe inside the steam generator, (b) at low load or hot standby conditions, the operator is instructed to supply feedwater continously as much as possible, (c) instrument the piping upstream of the steam generator auxiliary feedwater nozzle to monitor temperature for detecting the onset of steam backleakage, and, proper maintance of check valves. (Serkiz, Test., 3; Carlson, Test., 12-13, 16)

11. The temperature monitoring system will consist of temperature sensors on the feedwater piping adjacent to the auxiliary feedwater nozzle on each of the steam generators at the Byron station, which will feed information to the plant process computer, programmed to alarm when an abnormally high temperature is detected in the bypass piping. (Pleniewicz, Test., 4; Serkiz, tr., 1000)

12, Temperature sensors will provide continous checking on check valve leakage, and during refueling and maintance outages one of the six inch valves and two of the eight four inch check valves will be inspected. (Pleniewicz, Tr., 1109, 1108)

13. The type of temperature sensors used will be RTD's (Pleniewicz, Tr. 1106)

14. There have been cases of RTD's failing. (Pleniewicz, Tr., 1106)

15. It is possible that a schedule of check valve or sensor maintance might be valuable in predicting the probability of water hammer bubble collapse occurrance at a facility. (Serkiz, Tr., 1004)

17. Mr. Serkiz is not familiar with either maintance or in-

spection proceedures or matters of that nature with respect to the check valves or temperature sensors at the KRSKO plant. (Serkiz, Tr., 1003)

17. Mr. Carlson is familiar with the application of check valves in systems; their purpose, but not with the more operational consideration such as valve maintenance, leakage rates, etc. (Carlson, Tr. 907)

18. The recommended refill rate was derived from an analytical study done by the Westinghouse R & D. (Carlson, Test., 13)

19. If backleakage is detected, the piping should be slowly refilled or the plant brought to a cold shutdown condition, depending on the circumstances. (Carlson, Test., 16)

20. Edison is developing procedures which will instruct the reactor operator, if the temperature monitoring system indicates backleakage,,to slowly purge the bypass piping of the steam or hot water by introducing feedwater into the bypass piping through the tempering line at a flow rate as close as possible to the 15 gpm recommended by Westinghouse. (Pleniewicz, Test., 5)

21. The Hot Functional testing will determine the ability of the tempering flow system to achieve the low flow rate recommended by Westinghouse for refilling of the bypass piping. (Pleniewicz, Test., 7)

22. In general, the water level in the steam generator, unless it's under an accident sequence such as a feed line break or turbine trip, would not fall below the main or auxiliary feedwater nozzles. (Carlson, Tr., 1062, Pleniewicz, Test., 6)

23. The KRSKO water hammer event is within the purview of Unresolved Safety Issue A-1, Waterhammer. (Serkiz, Tr. 1010)

24. 24. Waterhammer is treated as a generic issue by the NRC yet, every occurance of waterhammer, including bubble collapse waterhammer is considered to be plant specific. (Serkiz, Tr., 1009-1010)

25. Staff does not have a task force studying waterhammer. (Serkiz, Tr. 949)

26. The Auxiliary Systems Branch and the Reactor Systems Branch are the primary NRC branches involved in reviewing waterhammer. (Serkiz, Tr., 949)

27. Staff has not directly investigated the KRSKO waterhammer event. Staff has only visited the facility recently as part of the IAEA investigation of Flow-induced Vibration at the plant. (Tr., 1022-1027)

28. Serkiz was responsible for conducting the NRC evaluation of the KRSKO event, the KRSKO and Byron plant designs, and the Westinghouse recommendations. (Serkiz, Test., 1; Tr., 948)

29. NRC Staff's review of the KRSKO event has relied upon information recieved from Westinghouse and Commonwealth Edison. (Serkiz, Tr., 949-952, 957)

30. Staff information on the KRSKO event has come from a meeting with Westinghouse and Commonwealth Edison staff on July 27, 1982, and a September 9, 1982 memorandum. (Serkiz, Test., 2)

31. Staff used it's information about the KRSKO event to evaluate the generic implications of bubble collapse waterhammer to preheat steam generators. (Serkiz, Test., 958)

32. The Staff position that the KRSKO event is plant-specific and not generic in nature is based upon the generic review in NUREG-3090, "Evaluation of Waterhammer Potential in Preheat Steam Gener-

ators," December 1982. (Serkiz, Test. 5)

33. Staff did not participate directly in drawing up NUREG-3090, but Serkiz provided the contractor with the information it used to evaluate the KRSKO event, and design specifics for the McGuire, Summer and Byron plants. (Serkiz, Tr. 973, 974)

34. Other than the same information provided Staff concerning backleakage, the NRC could not obtain explicit details of the conditions at the time of the event, including the type of pre-operational testing underway; whether procedures were being followed or some type of specialty tests being performed. Lacking the specifics on what was going on, Staff categorized the KRSKO event as a plant specific event and not generic in nature. (Serkiz, Tr., 1027-1029)

35. Staff's conclusion that the KRSKO event was plant specific and not generic was not intended to imply it could not occur in domestic reactors. (Serkiz, Tr. 1028)

36. The KRSKO event reveals that a waterhammer (due to bubble collapse) can occur in a plant which employs preheat steam generators. (Serkiz, Test., 3; Tr., 972)

37. Westinghouse's recommendations constitute good engineering design practices and prudent operating procedures. (Serkiz, Tr. 962)

38. Serkiz statement is based upon the assumption that good engineering design practices and prudent operating procedures will be followed. (Serkiz, Tr. 968-969; 965- 967)

39. Upon that basis, Serkiz is able to conclude that if those corrective measures recommended after the fact had been in place at the time of the event, particularly the continous feedwater

at the time of the event. particularly the continous feedwater flow in the auxiliary feedwater line, it would likely not have occurred. (Serkiz, Tr. 962)

40. That does not mean he has not known instances of faulty design or operation. (Tr. 969, Serkiz)

41. Applicant has indicated that warming flow to the auxiliary nozzle will be maintained during all phases of power operation, except the heat-up phase. (Serkiz, Test., 4)

42. During the normal operations of heat-up, cooldown, and hot standby, feedwater is supplied only through the auxiliary nozzle. However, only relatively small amounts of feedwater are required, not always enough to permit a continous flow. The opportunity does exist for backleakage if the check valves fail and low water level occurs. (Carlson, Test., 11)

43. The KRSKO waterhammer event did not compromise the ability of the affected systems to function. (Carlson, Tr., 1091)

44. There would be no consequences if a KRSKO-type waterhammer event of the same magnitude occurred at Byron; there would be no breach of the primary coolant system and thus no release of radiation. (Serkiz, Tr. 1019, 1020)

45. That the KRSKO event was at the upper end of the spectrum of possible bubble collapse waterhammer events involving that plant system is evident from the extent of the damage. (Carlson, Tr., 1111)

46. If the KRSKO event had been larger (which it is conceivable it could have been) the pipe could have ruptured. (Carlson, Tr., 1110)

47. It should be clearly stated that waterhammer will contin-

ue to occur. (Serkiz, Tr., 982; Carlson, Tr., 1130)

48. The number of instances that waterhammer would occur over the lifetime of a steam generator cannot be predicted. (Serkiz, Tr., 982)

49. The feedwater bypass system was developed and implemented to reduce the possibility of bubble collapse water hammer occurring in the preheater section of the steam generator, following an experimental program conducted by Westinghouse to investigate that possibility. (Carlson, Tr., 1045)

50. No testing evolved from that program or prior to the KRSKO event which could have led Westinghouse to conclude that the bypass system would be successful in minimizing preheater bubble collapse waterhammer, without in turn, inducing it in the bypass line itself. (Carlson, Tr., 1056-1061)

51. Westinghouse has recommended either replacement or removal of fast-acting check valves located near the auxiliary feedwater nozzle in Auxiliary Feedwater Systems because it is concerned over possible "acoustical" or classical waterhammer occurring in that location, against those valves, in the event of a feed line break. Edison has chosen to remove rather than replace the valves at Byron. (Carlson, Test., 14, 15; Tr., 1113, 1114)

52. The results of a bubble-collapse waterhammer and classical waterhammer events could be the same in their effects on piping systems. (Serkiz, Tr., 986, 987)

54. Waterhammer, whether classical or bubble collapse, will result in a change in water pressure. The change in pressure has the potential for damaging components of the piping system. The

pressure change, if large enough, may result in pipe deformation, or in an extreme case, rupture. It may also result in valve damage; for example, damage to valve packing and gaskets. The change in water pressure inside the system is accompanied by forces transmitted to the pipe supports. (Carlson, Test., 5)

55. There are fatigue factors associated with bubble collapse waterhammer occurring in the preheater section of a steam generator for the normal upset class of events. (Carlson, Tr., 1076)

56. Bubble collapse waterhammer in the preheater region or in the bypass line as at KRSKO have the common elements regardless of where they occur, with an enclosed, confined volume of steam being rapidly condensed when cold water is brought into contact with it, dependent upon the geometries involved. (Carlson, Tr., 1075, 1076)

57. Westinghouse anticipates Bypass System failure to occur on four ocassions within the 40-year lifespan of a steam generator. (Carlson, Tr., 1080)

58. The initial susceptibility of the Byron steam generators or feedwater system in the Byron Station will be determined during preoperational testing. (Pleniewicz, Test., 7; Serkiz, Test., 5)

59. NRC Staff is contemplating changes to the Standard Review Plan as resolution of USI A-1, Waterhammer. (Serkiz, Tr., 1012-1013)

60. The Byron plant will be the first operational plant which will implement the Westinghouse recommendations and which will, essentially have a feedwater system representative of the type of feedwater sytem KRSKO had at the time of the water hammer, as KRSKO's has now been modified to accommondate modifications to limit flow-induced vibration. (Carlson, Tr., 1099-1101)